MOVES2010a Update of the 2006 and 2018 On-Road Emission Inventories for Houston/Galveston/Brazoria (HGB)

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Presentation Overview

- EPA's On-Road Emission Estimation Models from 1978 to the Present
- On-Road Emission Inventory Development Basics
- Summary of Different 2006 and 2018 HGB On-Road Emission Estimates
- 2006 and 2018 HGB On-Road Emission Estimates Using MOVES2010a by County, Process, Vehicle Category, and Day Type
- Different On-Road Activity Inputs for Portions of Modeling Domain
- 2006 and 2018 On-Road NO_X Emission Plots for Portions of Modeling Domain
- Uncertainty in On-Road Emission Estimates
- On-Road Trends Study for 1999-2030 Using MOVES2010a
- Use of Trends Study to Back-Cast 2006 On-Road Emissions to 2000
- Background on Internal Engine Combustion Basics and Pollution Control
- Decline in Average NO_X, VOC, and CO Emission Rates from 1990-2050
- Change in NO_X, VOC, and CO Emission Rates by Model Year from 2010-2040
- Importance of Vehicle Miles Traveled (VMT) Allocation by Vehicle Type for Estimating Fleet Average NO_X Emissions
- Availability of Current MOVES Data Sets and Studies

Disclaimer: Emission estimates are rounded at two decimal places for reporting purposes.

EPA On-Road Emission Models Since 1978

EPA On-Road Model	Release Date/Year
MOBILE1	1978
MOBILE2	1981
MOBILE3	1984
MOBILE4	1989
MOBILE5	1993
MOBILE6	2002
MOBILE6.2	September 2003
MOVES2010	March 2010
MOVES2010a	September 2010
MOVES2010b	April 2012
MOVES2013	Sometime in 2013 or 2014

On-Road Emission Inventory Development Basics

- A State Implementation Plan (SIP) emissions inventory must be developed using the latest inputs available **AT THE TIME THE WORK IS DONE**.
  - Federal Clean Air Act, Section 172(c)(3)
  - 40 Code of Federal Regulations (CFR) Section 51.112(a)(1)
- For on-road emissions inventory development, the inputs that are most subject to change over time include:
  - The latest available version of the EPA emissions model (e.g., MOBILE6, MOBILE6.2, MOVES2010a, MOVES2010b, etc.)
  - VMT estimates from either the local travel demand model (TDM) or the Highway Performance Monitoring System (HPMS) data collected by the Texas Department of Transportation (TxDOT)
  - Projected age distribution by vehicle type of the fleet in a future year based on county-level queries of the vehicle registration database
- More time to perform the inventory development work leads to higher confidence and quality in the final emission estimates.
  - SIP-quality emissions inventory development can take several months.
  - Rough "need it now" estimates may only take a month or less, but rarely match or come close to the SIP-quality totals due to the simplifying assumptions that need to be made.

Eight-County HGB Area On-Road Emission Estimates Based on Different Models and Levels of Effort

Model Version and Level of Effort	Development Date	Daily VMT	2006 Summer Weekday Emissions (tpd)		
			NO_X	VOC	CO
MOBILE6.2 SIP-Quality	Summer 2007	133,868,661	206.74	90.71	1,115.28
MOVES2010 Sensitivity	Summer 2010	133,868,661	292.65	107.57	1,013.21
MOVES2010a SIP-Quality	Summer 2011	143,408,584	270.00	104.74	1,024.03

Model Version and Level of Effort	Development Date	Daily VMT	2018 Summer Weekday Emissions (tpd)		
			NO_X	VOC	CO
MOBILE6.2 SIP-Quality	Spring 2009	180,993,087	52.55	45.97	733.18
MOVES2010 Sensitivity	Summer 2010	180,993,087	109.07	48.10	617.79
MOVES2010a SIP-Quality	Winter 2012	180,955,402	103.34	50.13	656.24

2006 Summer Weekday HGB Area On-Road Emission Estimates Based on MOVES2010a by County

HGB Area County	Daily VMT	2006 Summer Weekday Emissions (tpd)				
		NO	NO_2	NO_X	VOC	CO
Brazoria	5,891,489	11.11	0.90	12.01	5.02	46.11
Chambers	2,760,121	10.20	0.79	11.00	1.46	18.82
Fort Bend	8,498,717	15.16	1.27	16.42	6.96	60.91
Galveston	6,023,802	9.90	0.82	10.73	5.05	47.36
Harris	105,560,026	171.13	14.67	185.80	75.22	741.49
Liberty	2,549,213	7.05	0.56	7.61	2.22	22.66
Montgomery	10,218,902	19.69	1.63	21.32	7.42	70.62
Waller	1,906,314	4.74	0.38	5.12	1.40	16.06
Total	143,408,584	248.97	21.02	270.00	104.74	1,024.03

2018 Summer Weekday HGB Area On-Road Emission Estimates Based on MOVES2010a by County

HGB Area County	Daily VMT	2018 Summer Weekday Emissions (tpd)				
		NO	NO_2	NO_X	VOC	CO
Brazoria	8,477,177	4.34	0.72	5.07	2.93	34.53
Chambers	3,831,327	3.33	0.71	4.04	0.71	11.94
Fort Bend	13,818,366	6.96	1.34	8.30	4.89	54.26
Galveston	6,898,244	3.16	0.54	3.69	2.24	27.35
Harris	126,846,143	56.93	10.59	67.51	32.89	448.17
Liberty	3,570,614	2.67	0.49	3.16	1.20	14.94
Montgomery	14,873,870	7.76	1.53	9.30	4.56	54.45
Waller	2,639,660	1.86	0.40	2.26	0.71	10.60
Total	180,955,402	87.01	16.33	103.34	50.13	656.24

2006 Summer Weekday HGB Area On-Road Emission Estimates Based on MOVES2010a by Aggregate Process

Aggregate Emission Process	2006 Summer Weekday Emissions (tpd)				
	NO	NO_2	NO_X	VOC	CO
Running Exhaust (includes crankcase)	212.04	19.43	231.47	31.86	729.73
Start Exhaust (includes crankcase)	31.85	1.24	33.09	33.95	291.34
Extended Idle Exhaust (includes crankcase)	5.08	0.35	5.43	2.03	2.96
Evaporative (includes permeation, fuel vapor venting, and fuel leaks)				36.90	
Total	248.97	21.02	270.00	104.74	1,024.03

2018 Summer Weekday HGB Area On-Road Emission Estimates Based on MOVES2010a by Aggregate Process

Aggregate Emission Process	2018 Summer Weekday Emissions (tpd)				
	NO	NO_2	NO_X	VOC	CO
Running Exhaust (includes crankcase)	65.98	13.26	79.24	10.56	440.12
Start Exhaust (includes crankcase)	16.34	0.94	17.28	20.55	212.16
Extended Idle Exhaust (includes crankcase)	4.68	2.14	6.82	1.30	3.95
Evaporative (includes permeation, fuel vapor venting, and fuel leaks)				17.72	
Total	87.01	16.33	103.34	50.13	656.24

2006 and 2018 Eight-County HGB Area Summer Weekday On-Road Emission Estimates by Vehicle Type

Aggregate Vehicle Type	Daily VMT	2006 On-Road Emissions (tpd)				
		NO	NO_2	NO_X	VOC	CO
Passenger Cars and Trucks	124,957,828	112.09	11.23	123.32	83.91	817.19
Medium-Duty Trucks	12,745,139	42.40	3.23	45.63	13.95	156.68
Heavy-Duty Trucks	5,239,444	88.44	6.14	94.58	6.49	47.87
Buses	466,173	6.04	0.42	6.46	0.39	2.29
Total	143,408,584	248.97	21.02	270.00	104.74	1,024.03

Aggregate Vehicle Type	Daily VMT	2018 On-Road Emissions (tpd)				
		NO	NO_2	NO_X	VOC	CO
Passenger Cars and Trucks	157,405,219	41.48	5.73	47.21	40.44	515.72
Medium-Duty Trucks	16,211,206	16.31	3.47	19.78	6.65	117.75
Heavy-Duty Trucks	6,771,947	26.85	6.81	33.66	2.85	21.45
Buses	567,030	2.37	0.31	2.68	0.19	1.32
Total	180,955,402	87.01	16.33	103.34	50.13	656.24

2006 and 2018 Eight-County HGB Area On-Road Emission Estimates With MOVES2010a by Day Type

Summer Day Type	Daily VMT	2006 On-Road Emissions (tpd)				
		NO	NO_2	NO_X	VOC	CO
Weekday	143,408,584	248.97	21.02	270.00	104.74	1,024.03
Friday	155,151,259	262.31	22.38	284.69	108.78	1,088.33
Saturday	124,752,878	188.13	16.43	204.56	88.27	856.57
Sunday	104,841,414	155.39	13.54	168.93	81.76	757.25

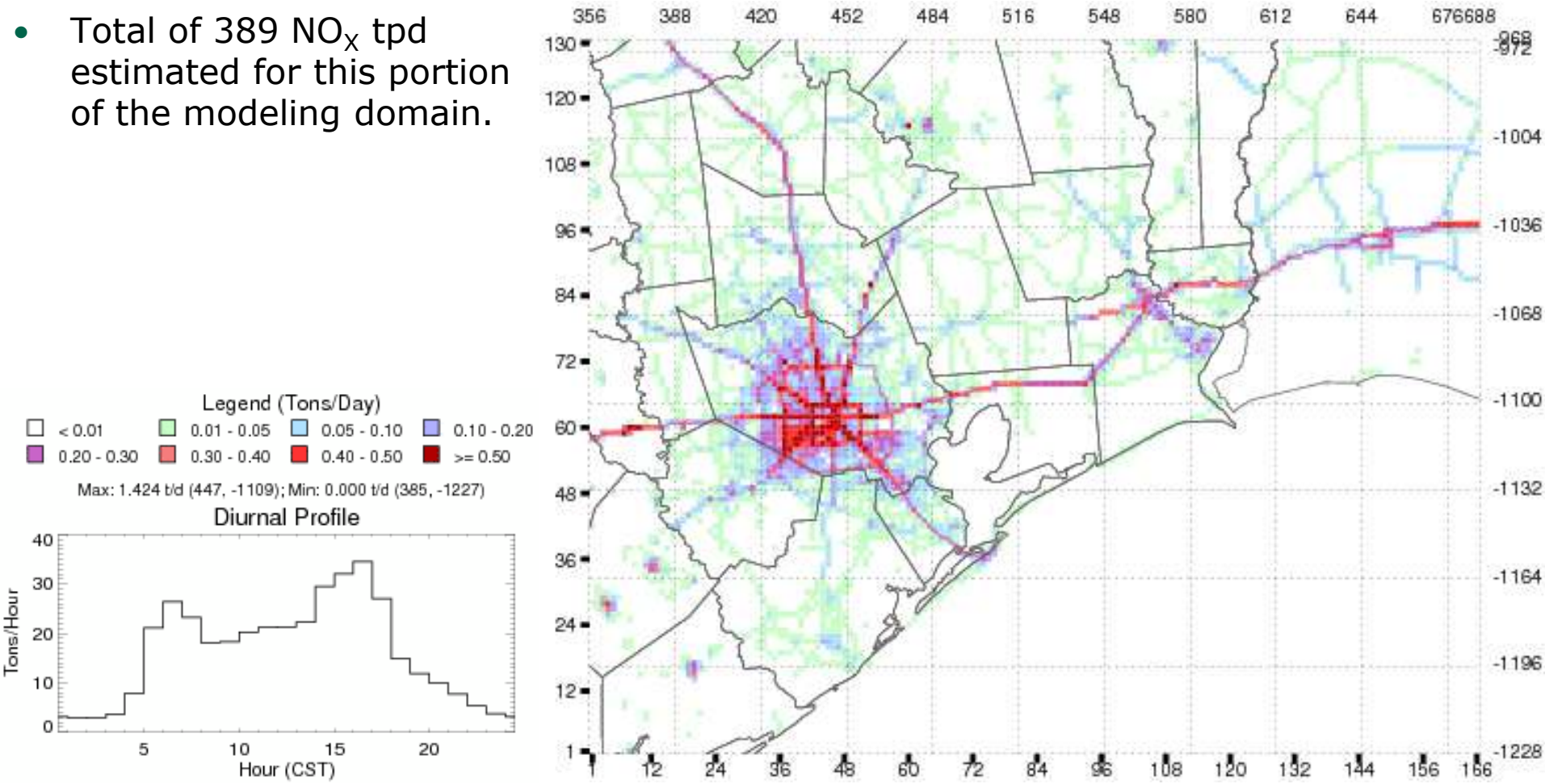
Summer Day Type	Daily VMT	2018 On-Road Emissions (tpd)				
		NO	NO_2	NO_X	VOC	CO
Weekday	180,955,402	87.01	16.33	103.34	50.13	656.24
Friday	195,069,658	91.33	17.20	108.54	51.46	693.97
Saturday	157,008,112	66.37	11.96	78.33	43.11	540.43
Sunday	131,735,508	55.73	9.59	65.33	40.83	480.17

Types of Vehicle Activity Data Sets Used for Estimating On-Road Emissions in the Modeling Domain

Geographic Area	VMT Data Source	Calendar Years
Eight-County HGB	Individual Roadway "Links" from Local TDM	2006 and 2018
Twelve-County Dallas-Fort Worth (DFW)		2006
Remaining Texas Counties	19 Roadway Types from HPMS	2006 and 2018
Non-Texas U.S.	Defaults Supplied with MOVES2010a	2006 and 2018

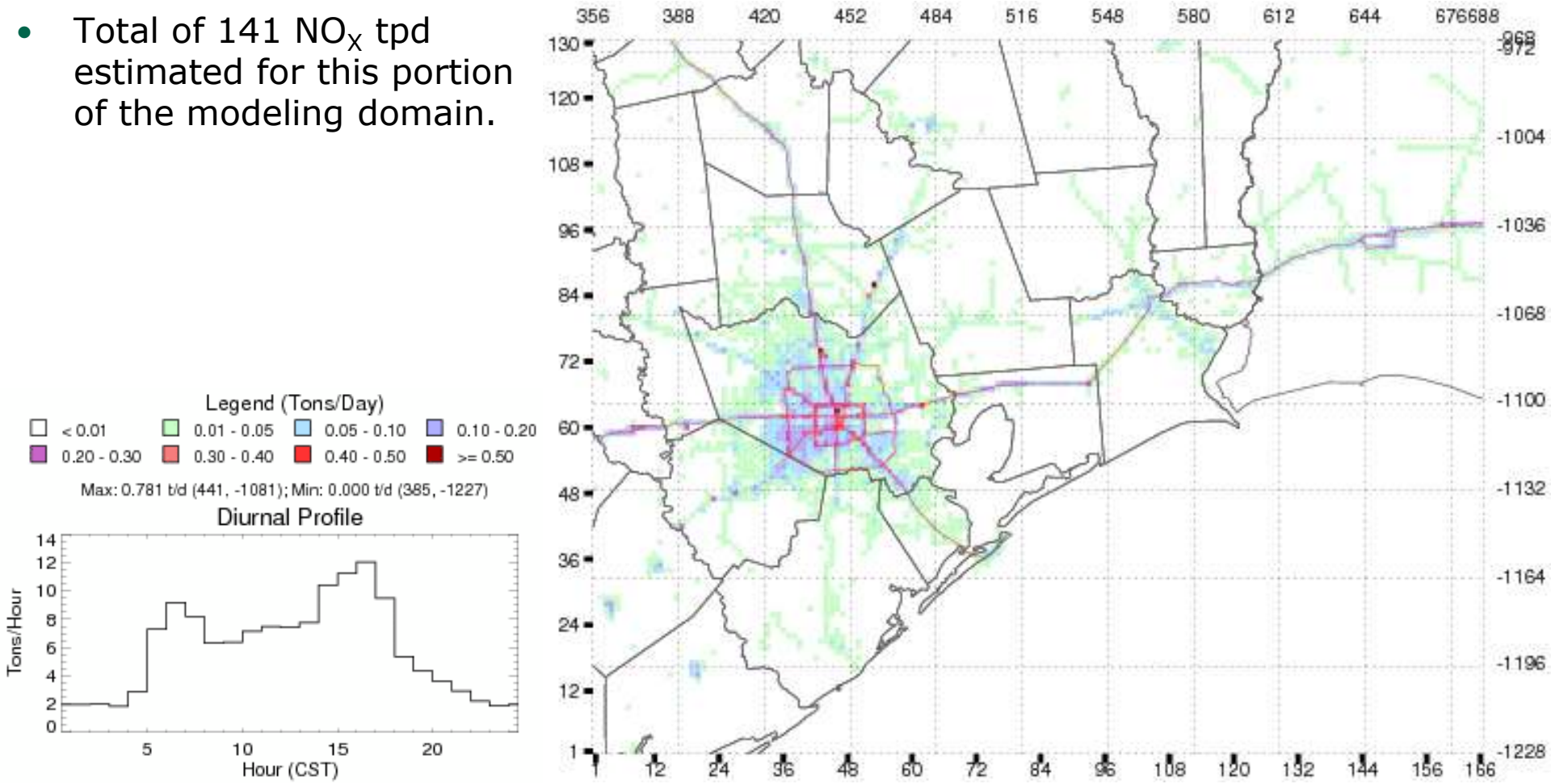
2006 Summer Weekday On-Road NO_X Emissions for Fine Grid Portion of Modeling Domain

- Total of 389 NO_X tpd estimated for this portion of the modeling domain.



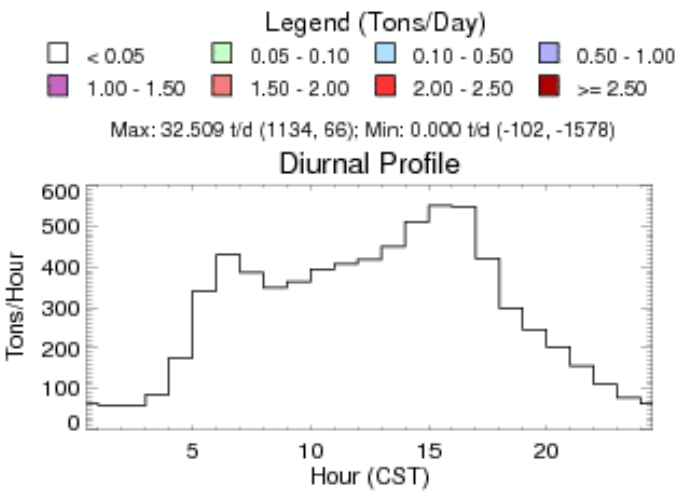
2018 Summer Weekday On-Road NO_X Emissions for Fine Grid Portion of Modeling Domain

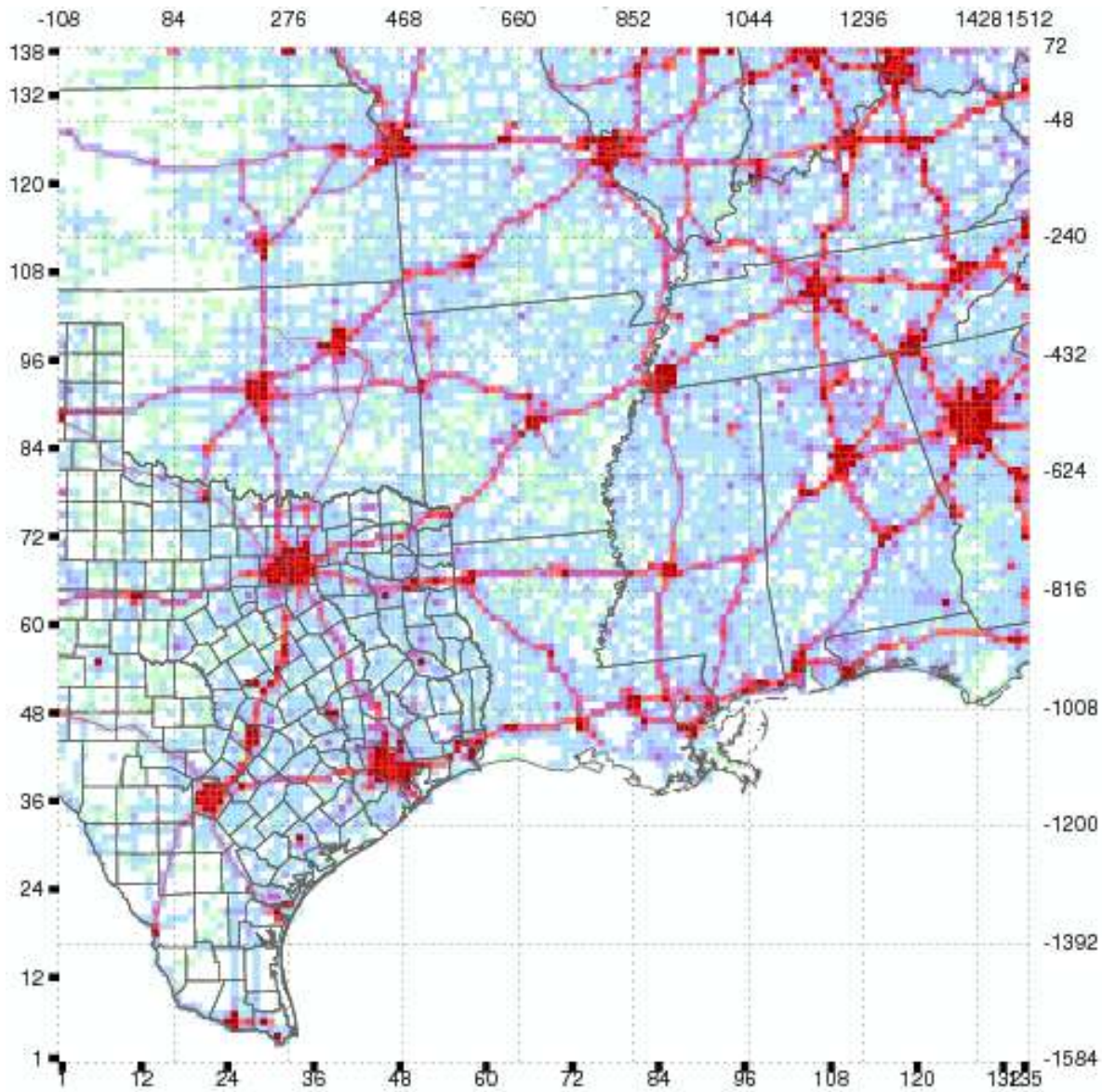
- Total of 141 NO_X tpd estimated for this portion of the modeling domain.



2006 Summer Weekday On-Road NO_X Emissions for Regional Portion of Modeling Domain

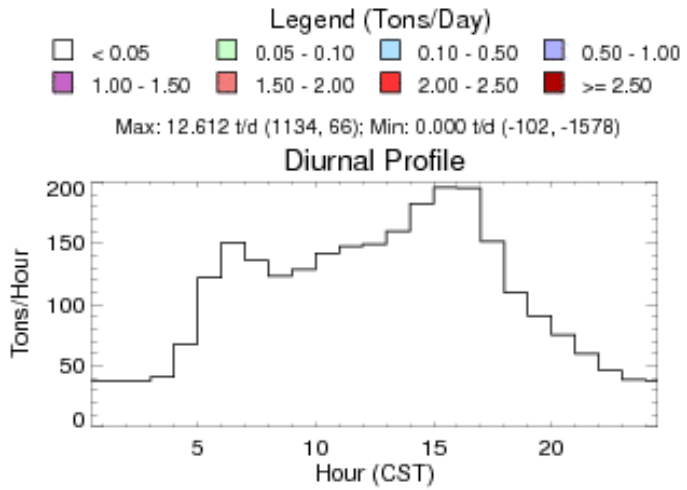
- Total of 7,104 NO_X tpd estimated for this portion of the modeling domain.

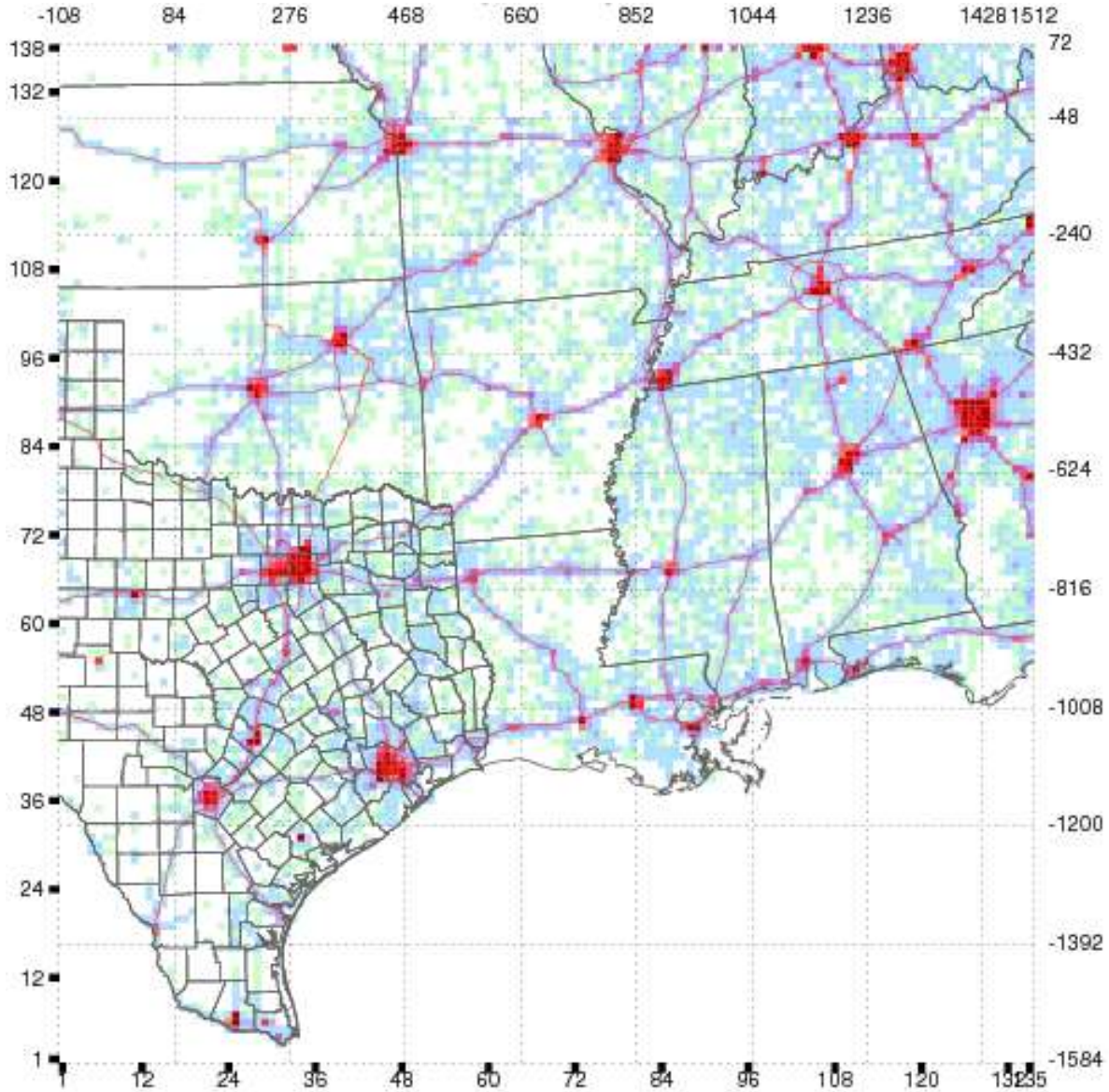




2018 Summer Weekday On-Road NO_X Emissions for Regional Portion of Modeling Domain

- Total of 2,625 NO_X tpd estimated for this portion of the modeling domain.





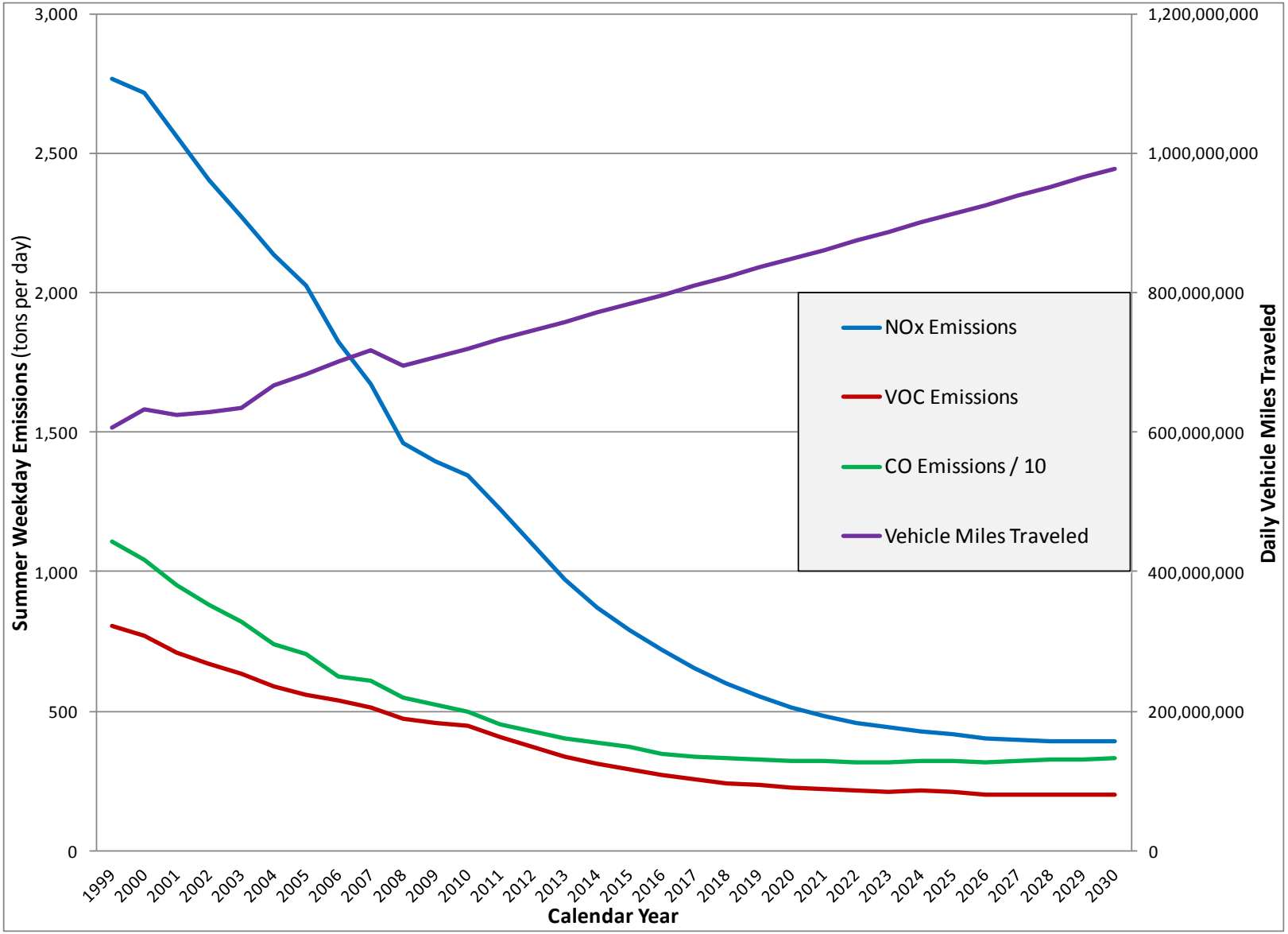
Uncertainty in On-Road Emission Estimates

- All of the emission estimates and the models upon which they are based contain uncertainty.
- The greatest difficulty with the accuracy of on-road models is that they are developed to estimate emissions from vehicles/engines with technologies that are either very new or have not yet been introduced to the fleet.
- The bulk of the MOBILE6 model development was done in the late 1990s when:
  - 1994-and-newer model year Tier 1 vehicles had just started entering the fleet;
  - 2004-and-newer model year Tier 2 vehicles did not yet exist; and
  - 2007-and-newer heavy-duty engines did not exist.
- MOVES contains improved information on Tier 1, Tier 2, and some heavy-duty engines:
  - Updated information will be included as it becomes available for all vehicle categories.
  - Even more stringent Tier 3 light-duty standards are under consideration and MOVES2013 will have to estimate their benefits before vehicles meeting such standards are available.
- Page 3 of EPA's guidance for attainment modeling and other analyses:

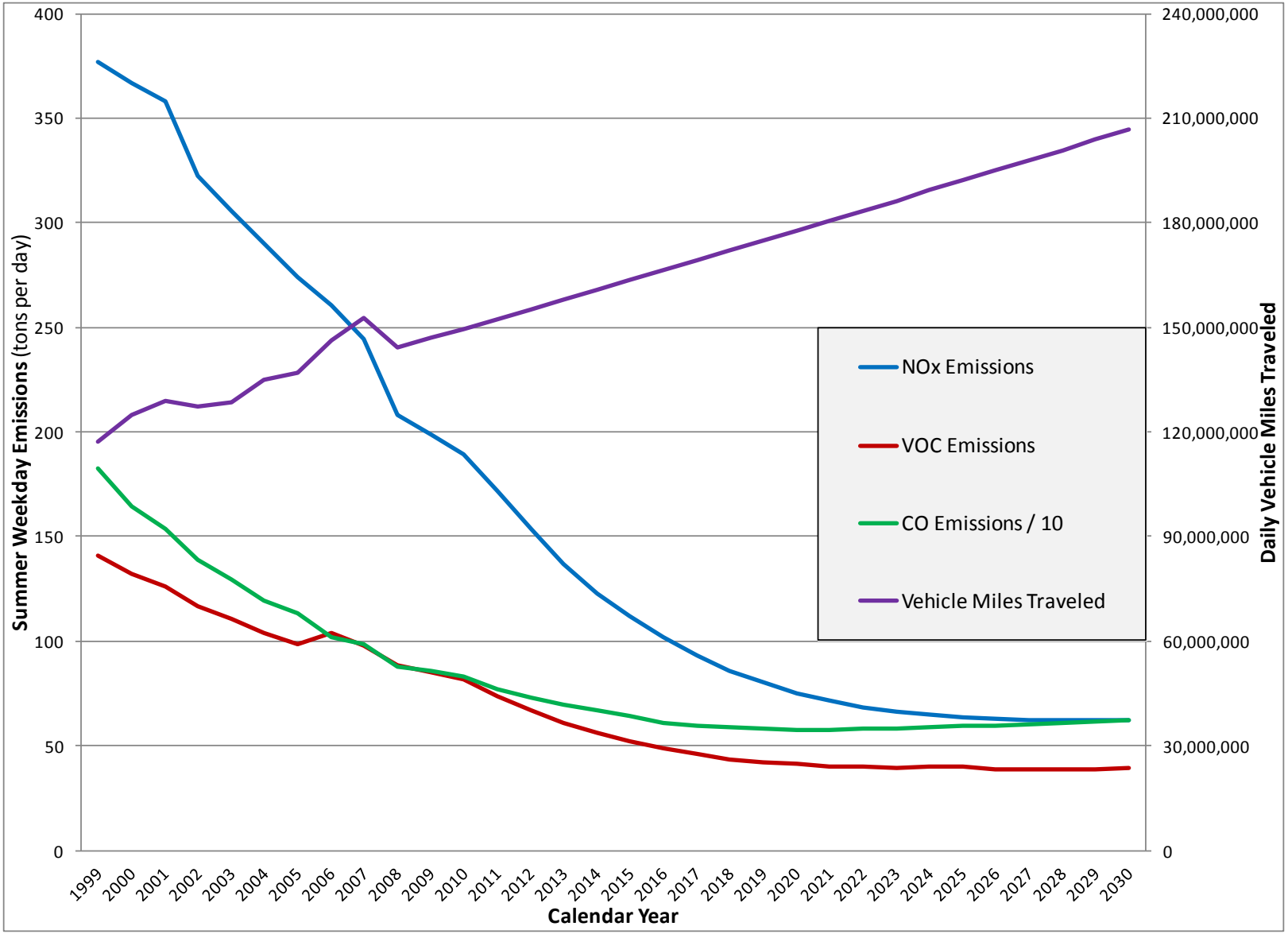
  http://www.epa.gov/ttn/scram/guidance/guide/final-03-pm-rh-guidance.pdf

  "**Premise 1. There is uncertainty accompanying model predictions.** "Uncertainty" is the notion that model estimates will not perfectly predict observed air quality at any given location, neither at the present time nor in the future…we recommend using models in a relative sense in concert with observed air quality data…we believe this approach should reduce some of the uncertainty attendant with using absolute model predictions alone."

MOVES2010a On-Road Emission Trends From 1999-2030 for All 254 Texas Counties



MOVES2010a On-Road Emission Trends From 1999-2030 for Eight-County HGB Area



Use of MOVES2010a On-Road Trends Data for 2000 Back-Cast Analysis

- 2000/2006 ratios from the trends analysis were developed for:
  - all 254 Texas counties;
  - each MOVES combination of fuel type and source use type (SUT); and
  - the pollutants of NO, NO_2, VOC, and CO.
- These ratios were applied to the 2006 MOVES2010a on-road inventories for each county and day type to develop an approximate set of 2000 on-road inputs for a back-cast sensitivity analysis.

Eight-County HGB On-Road Inventory Model and Calendar Year Scenario	**Summer Weekday Emissions** (tpd)				
	NO	NO_2	NO_X	VOC	CO
MOVES2010a for 2006	248.97	21.02	270.00	104.74	1,024.03
MOVES2010a 2006-to-2000 Sensitivity	352.09	30.14	382.23	134.27	1,651.25
MOBILE6.2 for 2000 from December 2004 SIP			341.75	150.52	2,108.32

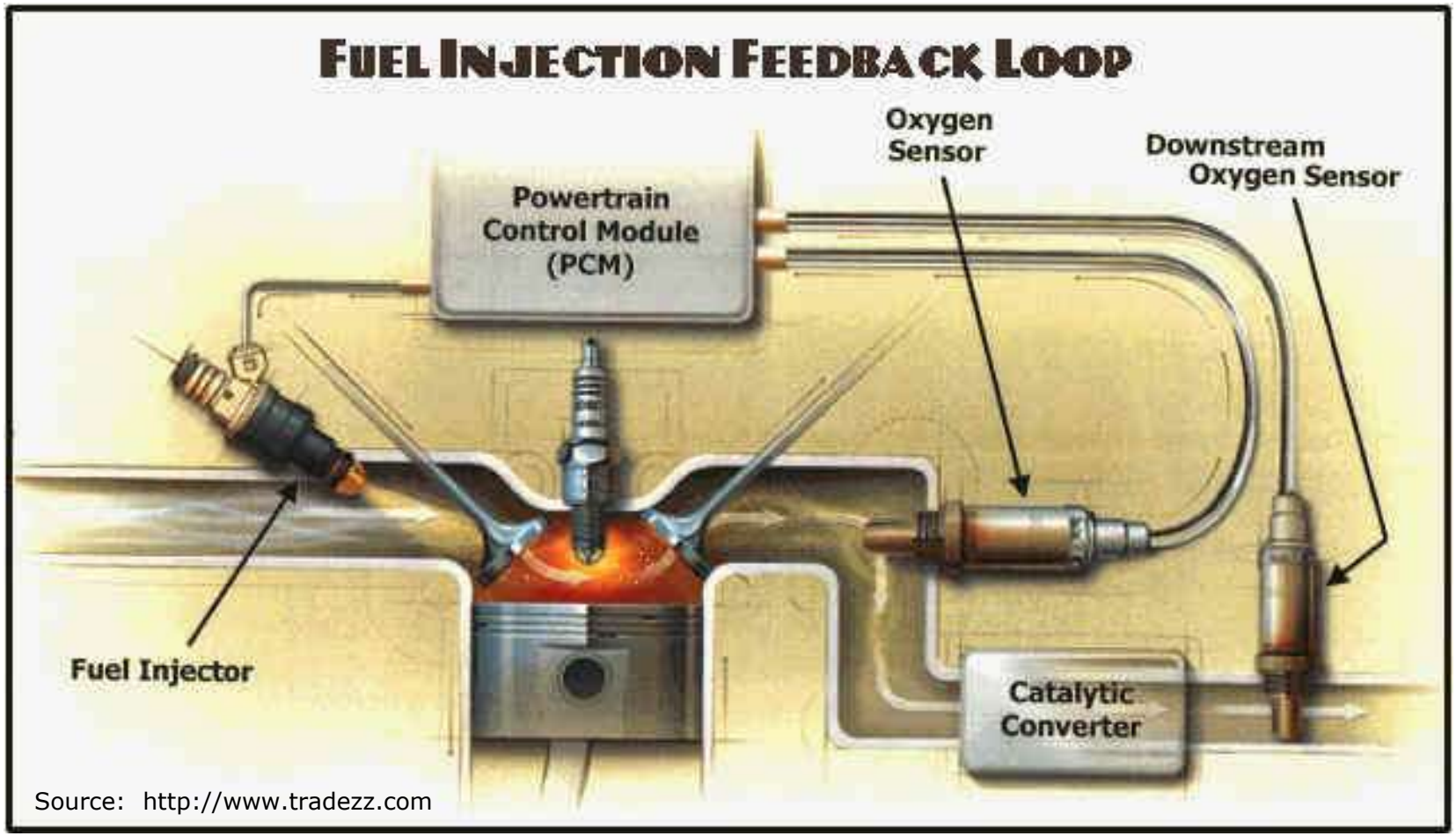
Background: Internal Combustion Engine Basics

- Perfect combustion to create heat energy for engine operation:
  - Hydrocarbon Fuel (H_XC_Y) + Oxygen(O_2) → Carbon Dioxide (CO_2) + Water Vapor (H_2O)
- Undesirable but unavoidable by-products of combustion:
  - Various HCs from incomplete combustion of fuel and incomplete oxidation to CO_2 and H_2O
  - VOC are total HC without methane (CH_4) and ethane (C_2H_6)
  - CO results from incomplete oxidation to CO_2
  - NO_X results from nitrogen (N_2) and O_2 in air combining at high temperature
- Energy content of various common fuels:

Fuel Description	**Gasoline Gallon Equivalent** (GGE)	**British Thermal Units** (BTUs) **per Gallon**
Diesel	0.88	129,500
Biodiesel (B100)	0.96	118,300
Gasoline	1.00	114,000
Liquefied Petroleum Gas (LPG)	1.35	84,300
Ethanol (E100)	1.50	76,100
Compressed Natural Gas (CNG)	5.66 pounds per GGE / 126.67 cubic feet / 900 BTU per cubic foot	

Background: Basic Engine Emission Control Schematic

- Reducing NO_X, VOC, and CO from modern engines:
  - on-board computer (e.g., powertrain control module) connected to various sensors
  - electronic fuel injection instead of mechanical carburetion
  - exhaust after-treatment (e.g., catalytic converter)



MOVES2010a Default Weighted Average NO_x Emission Rates from 1990-2050 (grams per mile)

Fuel	Source Use Type	1990	2000	2010	2020	2030	2040	2050
Gasoline	Motorcycle	0.8030	0.7013	0.5442	0.4484	0.4408	0.4383	0.4374
	Passenger Car	2.5363	1.7605	0.6841	0.1444	0.1015	0.0991	0.0971
	Passenger Truck	3.6398	2.5714	1.3971	0.6258	0.3646	0.3158	0.3107
	Light Commercial Truck	3.7153	2.6813	1.5422	0.7676	0.5113	0.4623	0.4569
	Motor Home	7.3234	5.3659	3.8426	2.7298	2.5017	2.4802	2.4802
Diesel	Light Commercial Truck	7.1808	7.5969	5.9438	2.6275	1.4164	1.0983	1.0803
	Intercity Bus	31.2949	25.1161	13.7183	4.7180	1.8244	1.2323	1.2296
	Transit Bus	26.6647	20.6521	11.0794	3.2992	1.2569	0.9662	0.9649
	School Bus	15.4386	11.8653	6.8167	2.5779	1.0271	0.7060	0.7044
	Refuse Truck	29.7003	22.1603	11.2550	2.9547	1.2557	1.1251	1.1245
	Single Unit Short-Haul Truck	17.7909	12.2175	5.2178	1.4013	0.8264	0.7676	0.7673
	Single Unit Long-Haul Truck	16.7496	10.3261	4.8122	1.4827	0.8401	0.7531	0.7527
	Combination Short-Haul Truck	34.9967	24.5616	11.3053	3.0490	1.3932	1.2465	1.2459
	Combination Long-Haul Truck	37.1860	27.2340	15.0181	6.8076	4.6797	4.4458	4.4450

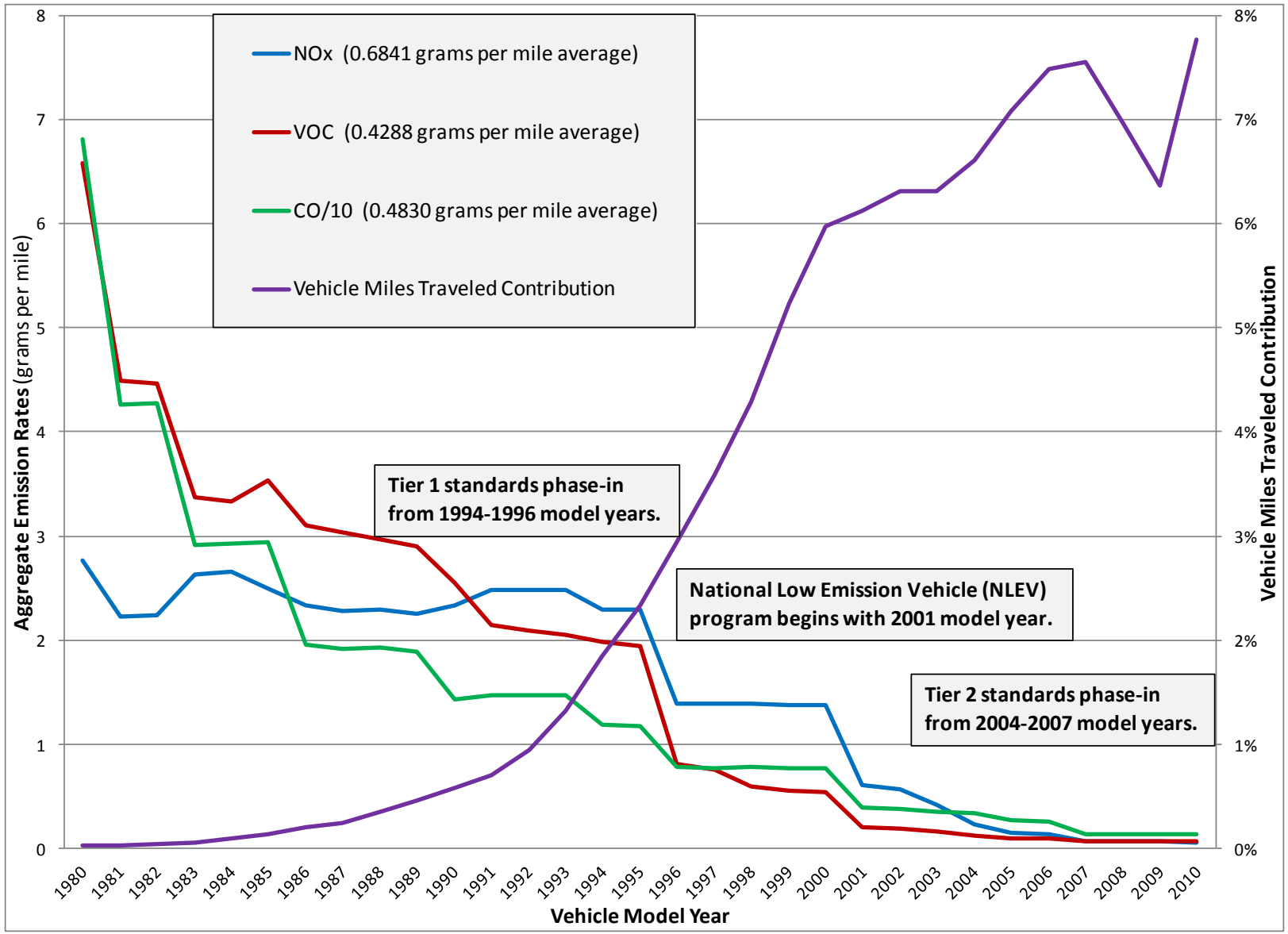
MOVES2010a Default Weighted Average VOC Emission Rates from 1990-2050 (grams per mile)

Fuel	Source Use Type	1990	2000	2010	2020	2030	2040	2050
Gasoline	Motorcycle	8.5360	4.7780	5.1589	6.1998	6.3239	6.0406	5.6144
	Passenger Car	2.7245	1.1915	0.4288	0.1499	0.1301	0.1246	0.1168
	Passenger Truck	3.6176	1.4901	0.8257	0.4008	0.2529	0.2158	0.1989
	Light Commercial Truck	3.4286	1.5546	0.8877	0.4369	0.2832	0.2447	0.2274
	Motor Home	5.5901	4.1197	3.2133	1.6744	1.2403	1.2149	1.2146
Diesel	Light Commercial Truck	0.8408	0.7613	0.7256	0.2439	0.0816	0.0430	0.0414
	Intercity Bus	0.9093	0.8650	0.7277	0.2749	0.0906	0.0440	0.0440
	Transit Bus	0.9464	0.9262	0.7791	0.2581	0.0666	0.0357	0.0357
	School Bus	0.6964	0.8189	0.6885	0.2621	0.0796	0.0370	0.0369
	Refuse Truck	0.8537	0.9594	0.7448	0.1829	0.0555	0.0440	0.0440
	Single Unit Short-Haul Truck	0.9627	1.0243	0.6598	0.1417	0.0532	0.0445	0.0445
	Single Unit Long-Haul Truck	0.8887	0.8497	0.6643	0.1664	0.0587	0.0450	0.0449
	Combination Short-Haul Truck	0.9087	0.8260	0.6772	0.1677	0.0528	0.0415	0.0415
	Combination Long-Haul Truck	2.9424	1.9508	1.6275	0.7667	0.5317	0.5022	0.5022

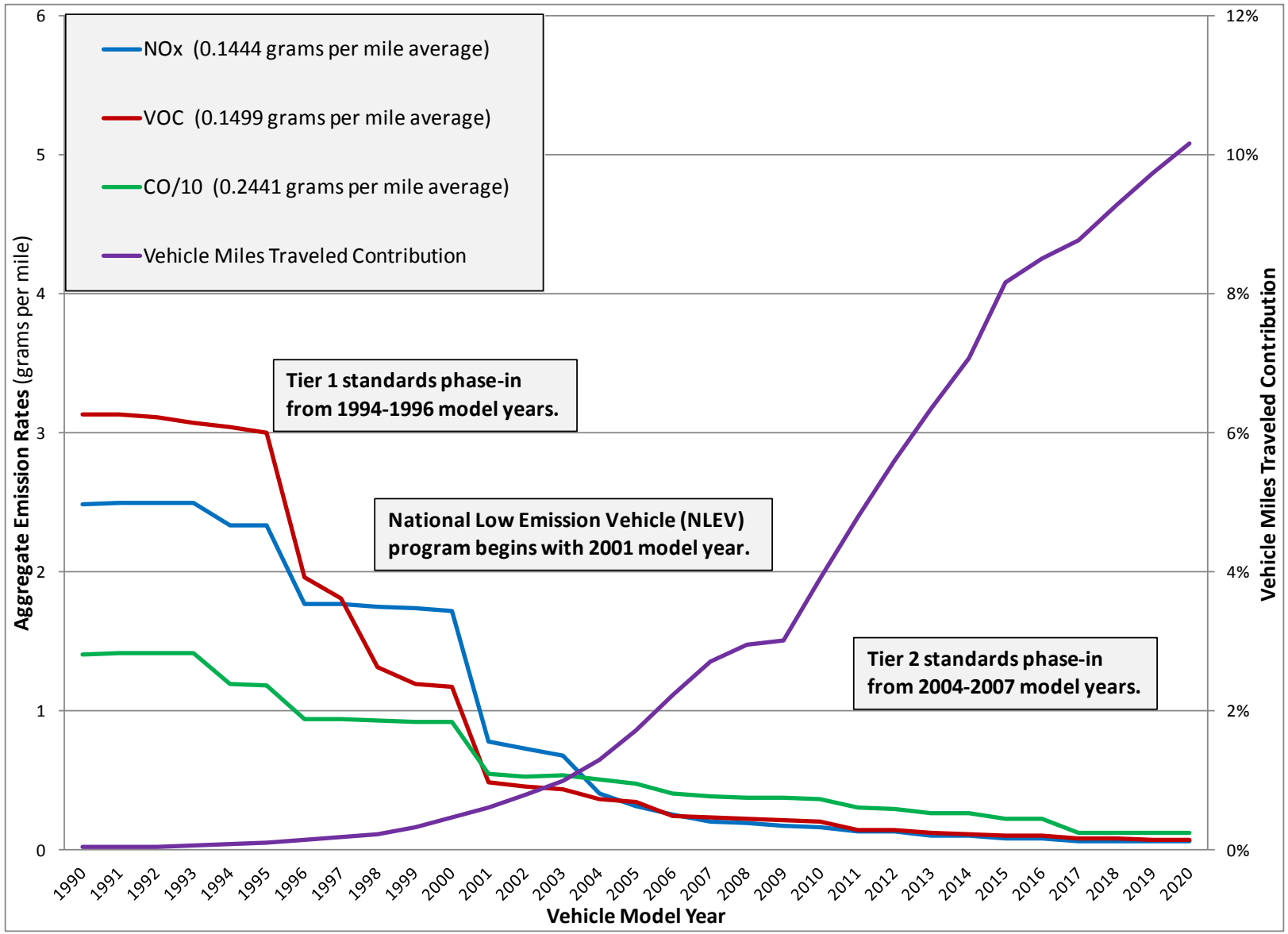
MOVES2010a Default Weighted Average CO Emission Rates from 1990-2050 (grams per mile)

Fuel	Source Use Type	1990	2000	2010	2020	2030	2040	2050
Gasoline	Motorcycle	37.0606	24.2495	13.6638	9.5345	9.0229	8.8417	8.8071
	Passenger Car	38.8631	13.8116	4.8295	2.4405	2.3910	2.3778	2.3431
	Passenger Truck	63.5824	21.4840	10.4830	5.6317	4.3814	4.0294	3.9021
	Light Commercial Truck	57.3360	22.1435	11.5266	6.5994	5.3607	4.9587	4.7761
	Motor Home	66.8682	61.3474	45.8368	30.5753	26.6470	26.6782	26.6339
Diesel	Light Commercial Truck	4.3948	4.5849	4.6425	2.3204	1.7695	1.6368	1.5930
	Intercity Bus	6.5739	6.2559	4.8358	2.0885	1.0769	0.8645	0.8630
	Transit Bus	6.3861	6.2297	5.4420	2.3868	1.4402	1.3173	1.3153
	School Bus	5.8254	6.1718	7.3531	5.3374	4.8547	4.7539	4.7433
	Refuse Truck	5.0982	5.5507	4.2046	1.4525	0.7980	0.7410	0.7402
	Single Unit Short-Haul Truck	4.0468	4.0213	3.1374	1.5150	1.2774	1.2585	1.2557
	Single Unit Long-Haul Truck	3.4982	3.1130	2.8615	1.4102	1.1228	1.0857	1.0834
	Combination Short-Haul Truck	5.3860	5.1620	3.7531	1.1646	0.5911	0.5373	0.5368
	Combination Long-Haul Truck	6.5232	6.8299	5.7878	3.1673	2.4605	2.3810	2.3805

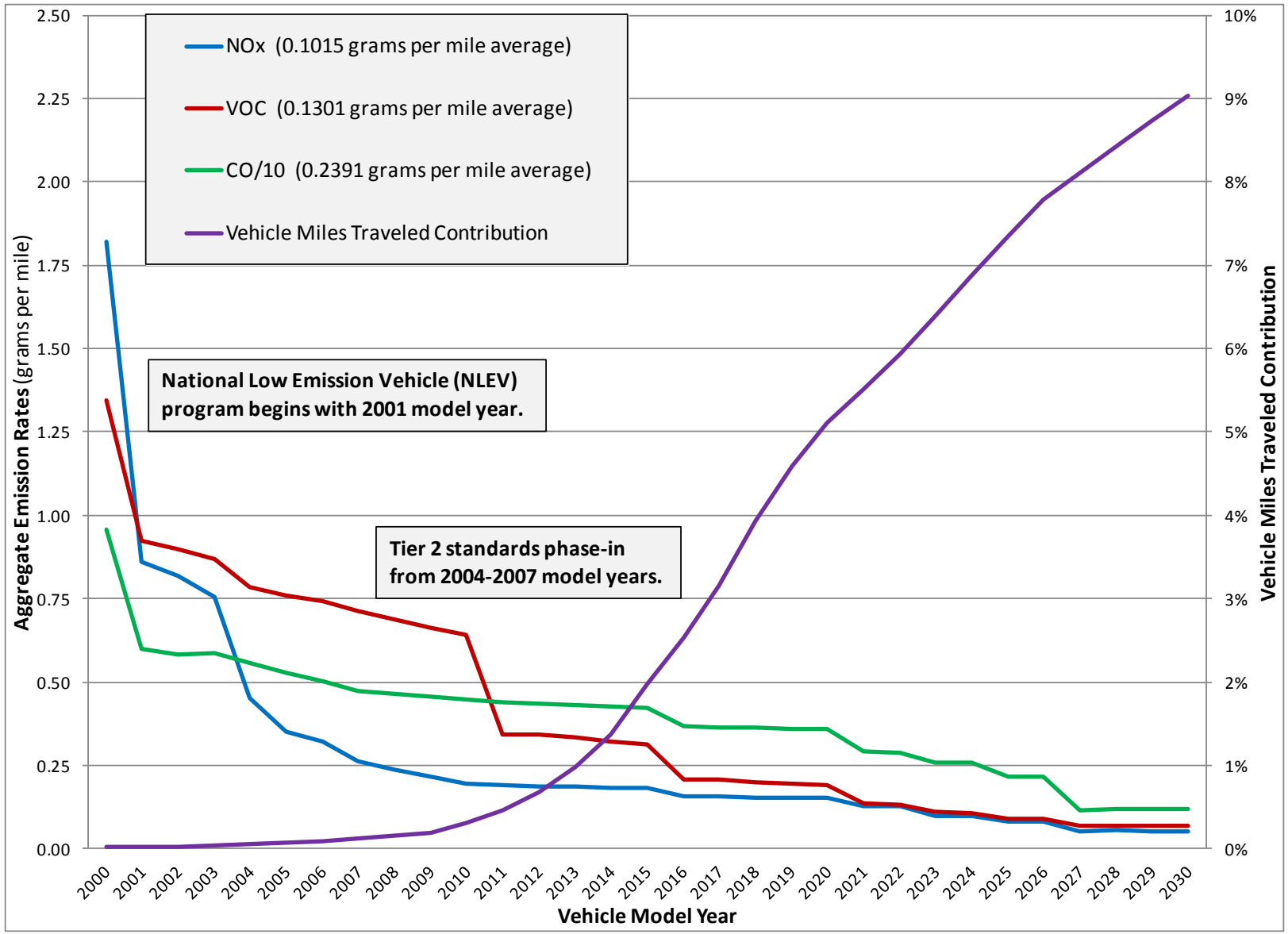
MOVES2010a Default Emission Rates by Model Year for Gasoline Passenger Cars Operating in 2010



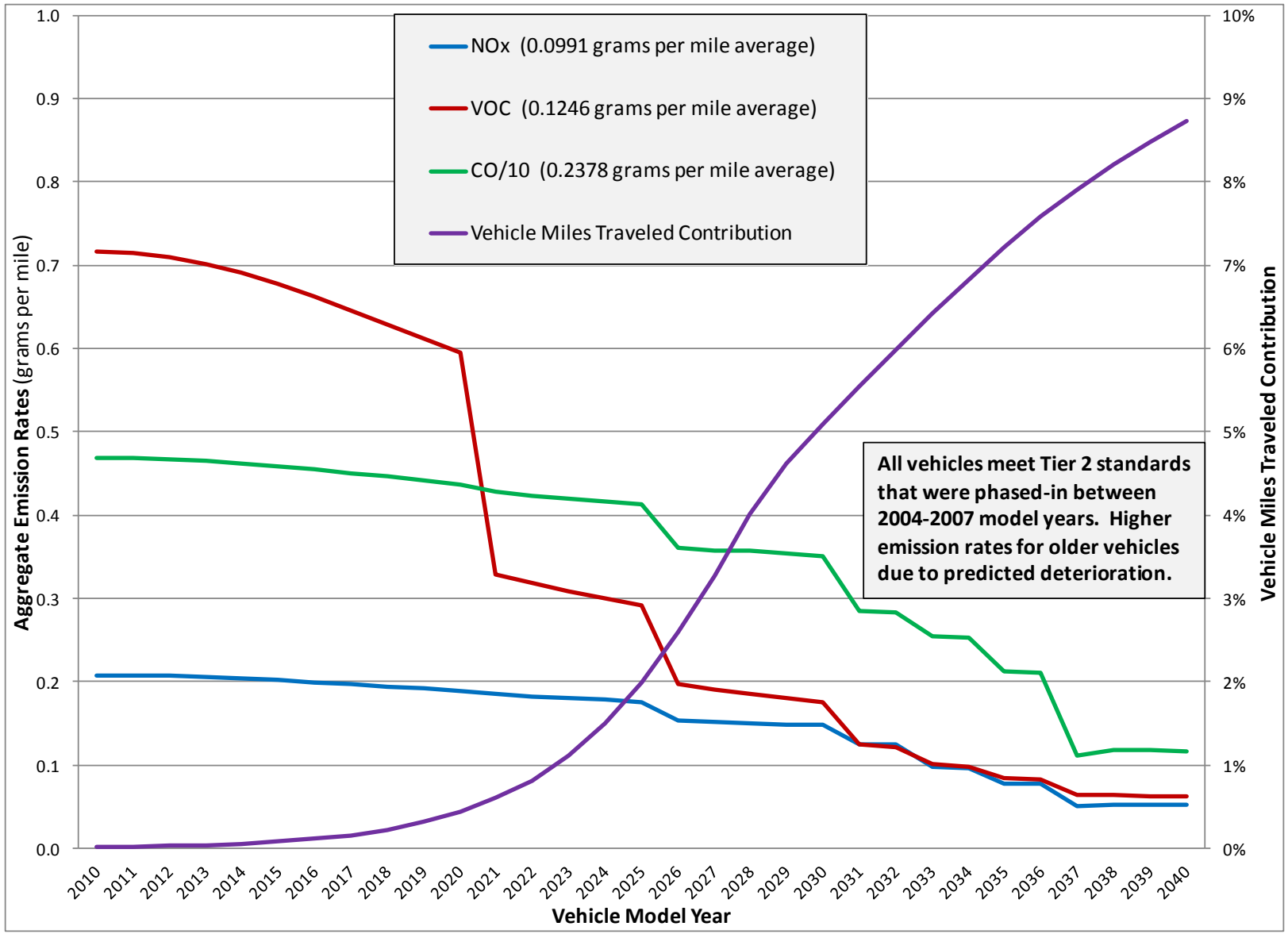
MOVES2010a Default Emission Rates by Model Year for Gasoline Passenger Cars Operating in 2020



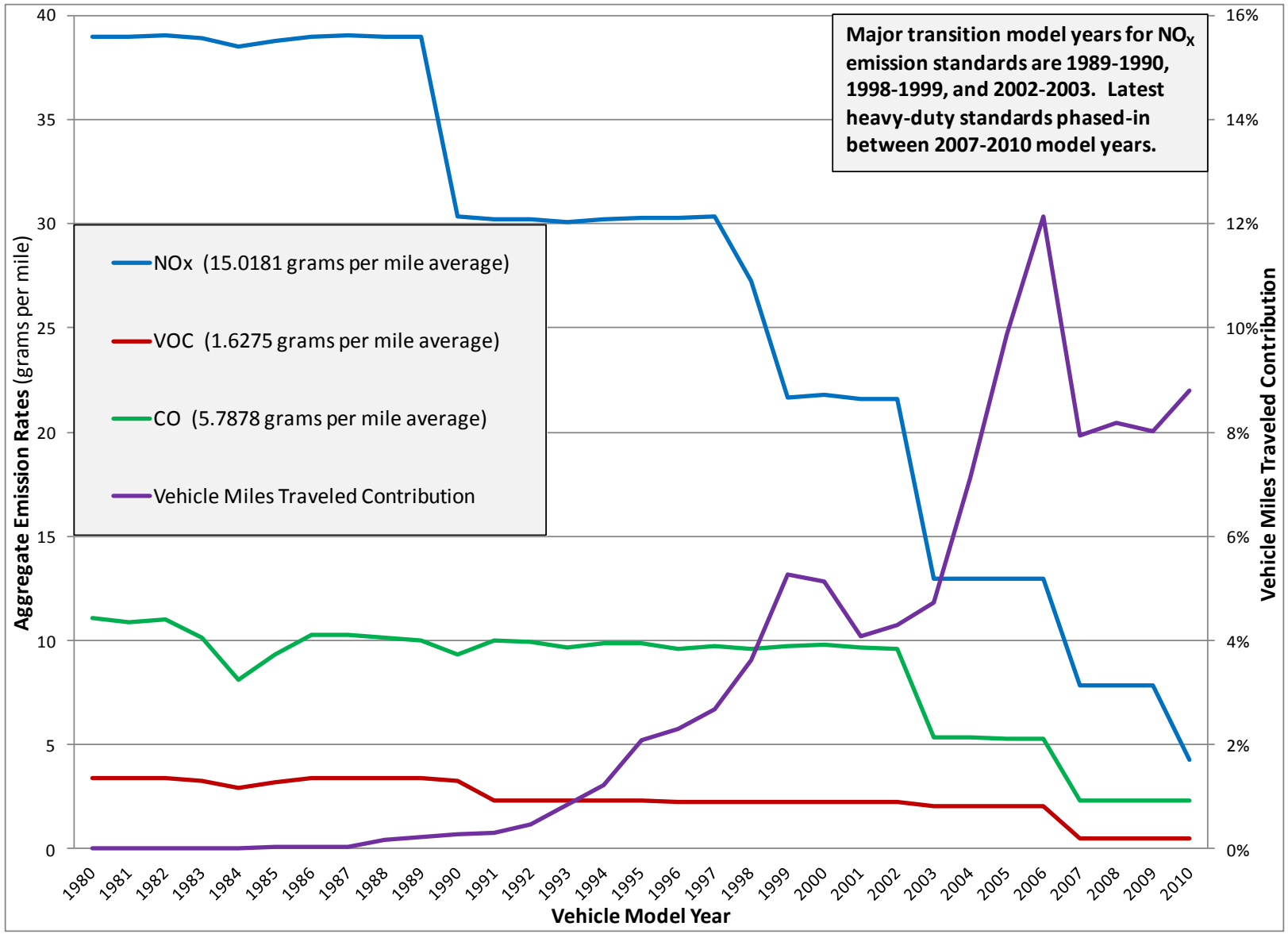
MOVES2010a Default Emission Rates by Model Year for Gasoline Passenger Cars Operating in 2030



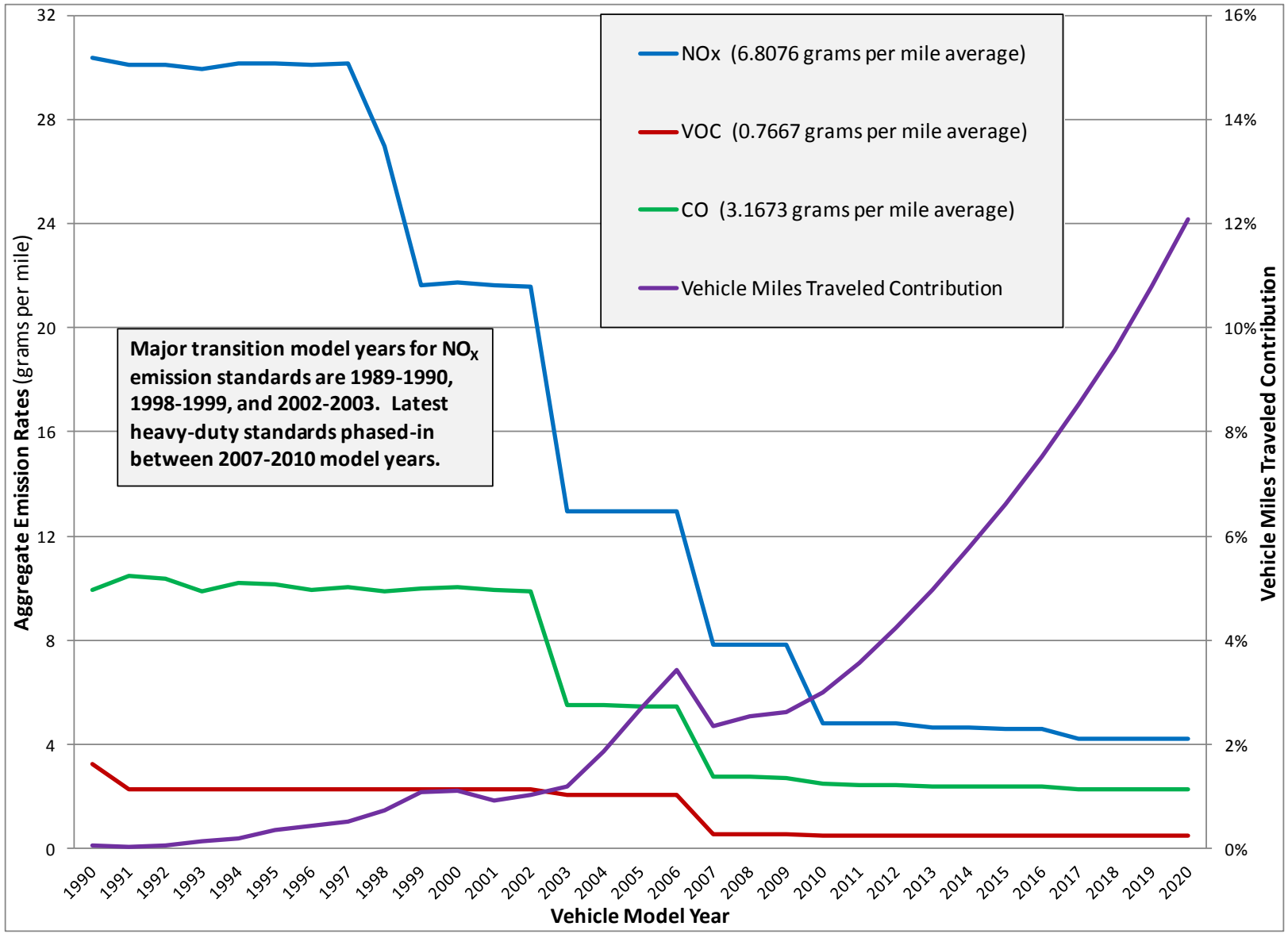
MOVES2010a Default Emission Rates by Model Year for Gasoline Passenger Cars Operating in 2040



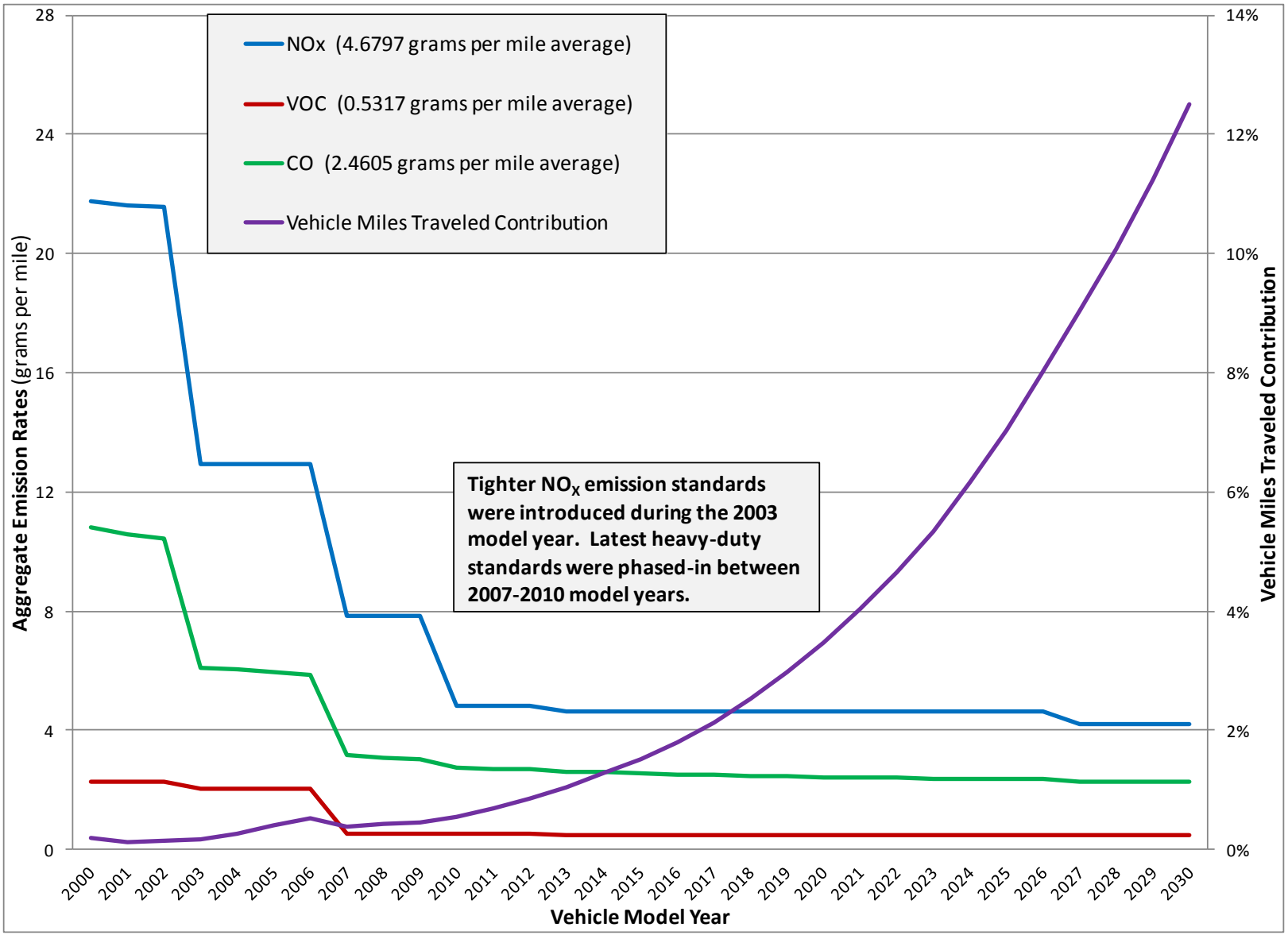
MOVES2010a Default Emission Rates by Model Year for Diesel Combination Long-Haul Trucks Operating in 2010



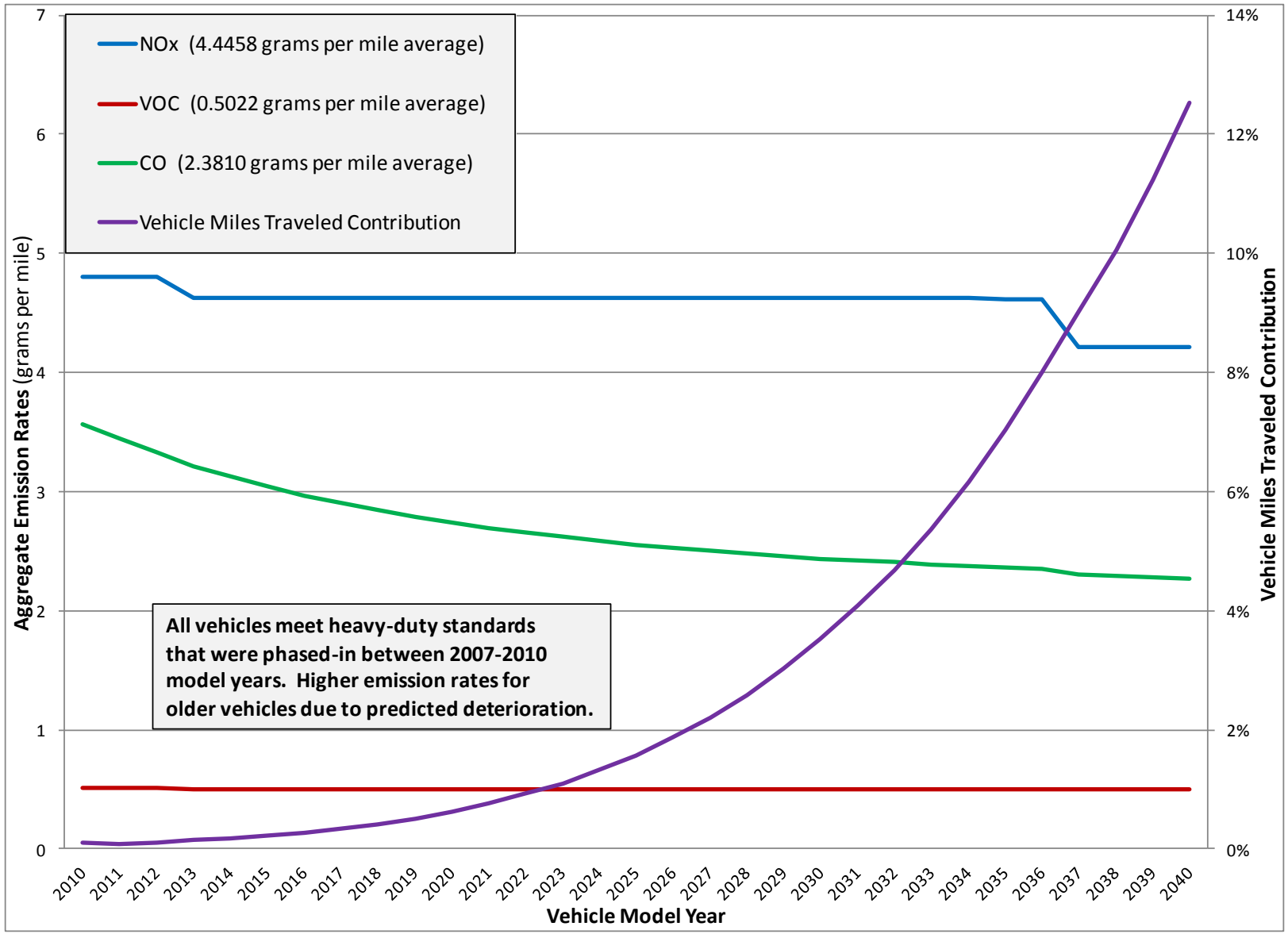
MOVES2010a Default Emission Rates by Model Year for Diesel Combination Long-Haul Trucks Operating in 2020



MOVES2010a Default Emission Rates by Model Year for Diesel Combination Long-Haul Trucks Operating in 2030



MOVES2010a Default Emission Rates by Model Year for Diesel Combination Long-Haul Trucks Operating in 2040



Example: Importance of Vehicle Miles Traveled Distribution ("VMT Mix") in Estimating Fleet Average NO_X Emissions

Fuel and Source Use Type	Average NO_X Emission Rate (grams per mile)						
	1990	2000	2010	2020	2030	2040	2050
Gasoline Passenger Car	2.5363	1.7605	0.6841	0.1444	0.1015	0.0991	0.0971
Diesel Combination Long-Haul Truck	37.1860	27.2340	15.0181	6.8076	4.6797	4.4458	4.4450
NO_X Ratio of Long-Haul Truck to Car	14.7	15.5	22.0	47.1	46.1	44.9	45.8

VMT Distribution		Weighted Fleet Average NO_X Emission Rate (grams per mile)						
Gasoline Passenger Car	Diesel Combination Long-Haul Truck	1990	2000	2010	2020	2030	2040	2050
100%	0%	2.5363	1.7605	0.6841	0.1444	0.1015	0.0991	0.0971
95%	5%	4.2688	3.0342	1.4008	0.4776	0.3304	0.3164	0.3145
90%	10%	6.0013	4.3079	2.1175	0.8107	0.5593	0.5338	0.5319
85%	15%	7.7338	5.5815	2.8342	1.1439	0.7882	0.7511	0.7493
80%	20%	9.4662	6.8552	3.5509	1.4770	1.0171	0.9684	0.9667
75%	25%	11.1987	8.1289	4.2676	1.8102	1.2461	1.1858	1.1841
70%	30%	12.9312	9.4026	4.9843	2.1434	1.4750	1.4031	1.4015
65%	35%	14.6637	10.6762	5.7010	2.4765	1.7039	1.6204	1.6189
60%	40%	16.3962	11.9499	6.4177	2.8097	1.9328	1.8378	1.8363
55%	45%	18.1287	13.2236	7.1344	3.1428	2.1617	2.0551	2.0537
50%	50%	19.8612	14.4973	7.8511	3.4760	2.3906	2.2725	2.2711

Availability of MOVES-Based On-Road Emission Inventory Data Sets and Studies

- TCEQ FTP site directories with more MOVES inventory development detail done primarily by the Texas Transportation Institute (TTI):
  - ftp://amdaftp.tceq.texas.gov/pub/Mobile_EI/DFW/mvs/ for DFW area
  - ftp://amdaftp.tceq.texas.gov/pub/Mobile_EI/HGB/mvs/ for HGB area
  - ftp://amdaftp.tceq.texas.gov/pub/Mobile_EI/Statewide/mvs/ for non-DFW and non-HGB Texas areas
  - ftp://amdaftp.tceq.texas.gov/pub/Mobile_EI/USA/mvs/ for non-Texas U.S. portions of modeling domain

- TCEQ FTP site directories with on-road photochemical modeling input files:
  - ftp://amdaftp.tceq.texas.gov/pub/Mobile_EI/DFW/eps3/ for DFW area
  - ftp://amdaftp.tceq.texas.gov/pub/Mobile_EI/HGB/eps3/ for HGB area
  - ftp://amdaftp.tceq.texas.gov/pub/Mobile_EI/Statewide/eps3/ for non-DFW and non-HGB Texas areas
  - ftp://amdaftp.tceq.texas.gov/pub/Mobile_EI/USA/eps3/ for non-Texas U.S. portions of modeling domain
  - ftp://amdaftp.tceq.texas.gov/pub/Mobile_EI/ALL/eps3/ for merged inputs from all areas

- Other TCEQ FTP site directories with on-road emission studies:
  - ftp://amdaftp.tceq.texas.gov/pub/Mobile_EI/MOVES/Utilities/ for MOVES inventory development utilities
  - ftp://amdaftp.tceq.texas.gov/pub/Mobile_EI/MOVES/Sensitivity/ for MOVES sensitivity analysis
  - ftp://amdaftp.tceq.texas.gov/pub/Mobile_EI/Trends/mvs/ for 1999-2030 on-road MOVES trends study

- TCEQ on-road mobile air quality research and contract reports web page:
  - http://www.tceq.texas.gov/airquality/airmod/project/pj_report_mob.html

Questions?

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